Effect of Goats on Great Island, Three Kings, with descriptions of Vegetation Quadrats.

By E. G. TURBOTT, M.Sc., Auckland Museum.

Goats, the most evidently destructive of man's animal satellites, have become naturalised on numerous islands of small or moderate area throughout the world. Their marked effect within the compass of such islands first became familiar through the dramatic accounts of Darwin (1839) and later of Wallace (1880), who describes the denuding of a "luxuriant forest vegetation" on St. Helena. In the Pacific this process, due partly or wholly to goats, has been repeated to varying degrees on a number of islands, for example on the Marquesas (Adamson, 1939); and has occurred in the New Zealand area on members of the Kermadec (Oliver, 1910), Auckland and Three Kings groups.

The effect of goats on the New Zealand mainland has been described by Thomson (1922), Moore and Cranwell (1934), Zotov *et al* (1939) and Wodzicki (ms.).

On Great Island, of the Three Kings group, the stock of goats which forms the subject of the present paper may have originated in part from animals introduced in the early nineteenth century; but is undoubtedly descended from four which, according to the records of the Marine Department, were placed on the island in November, 1889, to provide food for castaways.

The influence of the goats introduced to Great Island, and especially of the rapidly expanding population after 1889 (Baylis, 1948), has been imposed upon communities already considerably modified. As Baylis (ibid.) shows clearly in his account of the vegetation in this series, early Maori inhabitants cleared the island of much of the primary plant covering. Fortunately, Cheeseman (1888 and 1891) examined the vegetation in 1887, and again in 1889 when goats were liberated, and found that the greater part of the plant covering consisted of tea-tree (*Leptospermum scoparium* Forst. and *Leptospermum ericoides* A. Rich.) forest, which had evidently regenerated on the former Maori clearings.

In April, 1946, at the urgent suggestion of Mr. A. W. B. Powell, Assistant Director of the Auckland Museum, the Wild Life Branch of the Department of Internal Affairs sent an expedition of professional hunters to exterminate the then considerable goat population. The complete destruction of this population, numbering 393, by the Expedition, marks the beginning of a new phase in the ecology of Great Island: changes in both plant and animal elements in communities will now afford a unique opportunity to evaluate this major ecological factor.

I am indebted to the Department of Internal Affairs for my opportunity to visit the island as a member of the Expedition. Our party was landed on Great Island on 13th April, 1946, by the Works Department auxiliary ketch "New Golden Hind" in the course of her voyage to the Kermadec Islands. We re-embarked in the same vessel five weeks later, on 16th May.

EFFECT OF GOATS UPON COMMUNITIES.

(a) Plant Elements.

For a full account of the vegetation, reference should be made to the paper in this series by Baylis, who describes all modifying factors. Modification attributed to goats includes the extreme reduction or extinction of a number of plant species not referred to in the present paper.

A brief description of the effect of goats upon the vegetation, and of the vegetation quadrats, is contained in a report which I submitted to the Department of Internal Affairs on my return from the present Expedition (Turbott, 1946).

The plant covering over the greater part of the island at present consists of a sub-climax forest, with *Leptospermum ericoides* (kanuka) the sole dominant. Young *Leptospermum ericoides* grows vigorously where trees have fallen, breaking the canopy, and this species would appear to be avoided at all stages by goats (except when grazed at the seedling stage: see Appendix).

Widely scattered *Cordyline australis* (Forst. f.) Hook. f. (cabbage tree), and *Leptospermum scoparium* (manuka) in a few stands, may be locally co-dominant (Baylis, 1948). Baylis believes that *Leptospermum scoparium,* apparently to some degree palatable to goats, may have been replaced extensively by *Leptospermum ericoides.*

An extremely sparse undergrowth may be formed by two goat-resisting shrubs, *Coprosma rhamnoides* A. Cunn. and *Myoporum laetum* Forst. f. (ngaio); these even attaining subdominance (Baylis, ibid.) in certain areas. A few low plants and seedlings of *Melicope ternata* Forst. (wharangi) also occur, ranging in height from a few feet to three inches. These, although browsed or ring-barked (Fig. 15), are apparently unpalatable enough to survive, if only temporarily; no moderately high saplings of this species were observed, so that it is to be presumed that many of the young plants fail to survive.

The forest floor, particularly where the canopy is less dense, has a thick covering of the drooping sedge *Carex testacea* Boott., replaced to an increasing extent on damper ground by the more erect *Carex virgata* Hook. f. With these is mingled sparingly a third sedge, *Scirpus nodosus* Rottb. Between the sedges various mosses, grasses and herbs may be interspersed to form a matted turf.

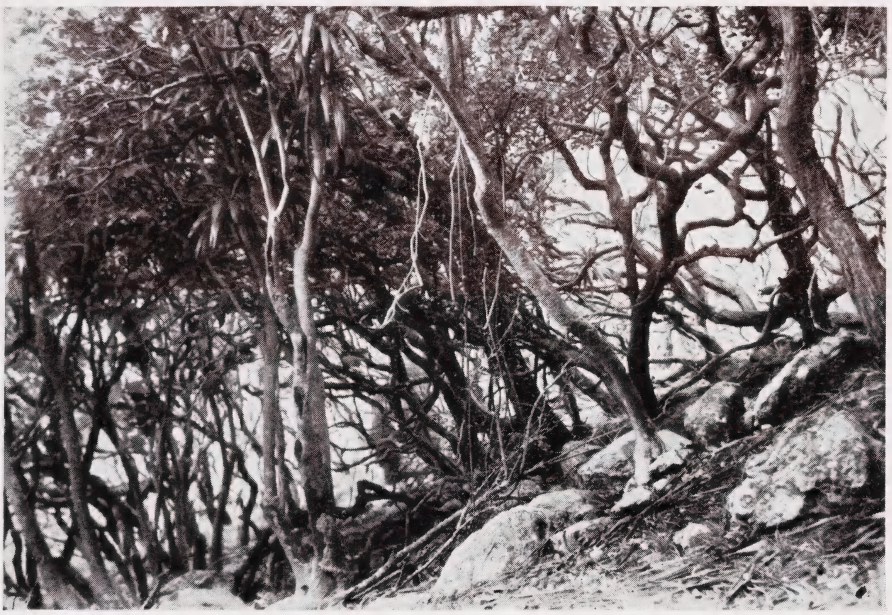

Fig. 3. A. Quadrat I, 29th April, 1946: area of south-west corner, showing *Clematis indivisa;* trunks of *Pittosporum fairchildii* (centre) and *Melicope ternata* (right); scattered *Carex testacea* on forest floor.

Fig. 4. B. Quadrat I, 6th May, 1946: south-western section, showing (left foreground) *Paratrophis smithii, Melicope ternata; Cordyline australis;* and (middle distance) *Litsaea calicaris.* Note *C. australis* barked by goats. Forest floor almost bare.

Fig. 5. C. Quadrat I, 29th April, 1946: area of north-west corner, showing young *Leptospermum ericoides* in opening, and *Cordyline australis;* dense *Carex* spp. and associated plants of ground layer.

Fig. 6. D. Quadrat I, 6th May, 1946: north-western section, showing (left) young *Leptospermum ericoides* replacing dead trees, and (right) *Litsaea calicaris*. Dense ground layer.

Leptospermum ericoides also forms shrubland and prostrate scrub, described thus by Baylis (ibid.) according to the growth-form of the dominant. *Leptospermum ericoides* shrubland occurs on areas considered to have been comparatively recently burnt, and *Leptospermum ericoides* scrub on part of the southern Tasman Valley where the effect of wind is particularly marked.

Leptospermum ericoides communities are replaced in only one considerable area by one of a different type: this is on the southern slopes of Tasman Valley, which is clothed over a considerable area by grassland, the dominant species being *Zoisia matrella* (L.) Merrill. Baylis (ibid.) considers that this grassland became established after relatively recent burning, and that slow invasion by the neighbouring *Leptospermum ericoides* shrubland had been taking place in the presence of goats.

Brief reference may be made to a sprawling scrub formed of *Myoporum laetum* on the screes and steep faces of seaward slopes; and to the small amount of unaltered shrubby and herbaceous vegetation, surviving only on the few cliff ledges inaccessible to goats.

The most remarkable characteristic of the vegetation, thus briefly described, is the extent and uniformity of the predominating *Leptospermum ericoides* communities. Of particular interest, therefore, especially in relation to the probable course of regeneration on the island, is the existence, scattered at wide intervals, of a number of groves and single individuals of large-leafed trees. These are to be regarded as remnants of the original climax forest, having probably persisted throughout the Maori occupation, in most cases on areas too rocky for cultivation. The original plant covering of Great Island is considered by Baylis (ibid.) to have consisted of a mixed coastal or semi-coastal forest, including certain endemic trees and shrubs which would have contributed a unique aspect.

At the time of the destruction of goats it was evident that climax remnants, including both trees and lianes, were of but impermanent status. The following list includes the more important species, given in order of frequency: *Metrosideros excelsa* Gaertn. (pohutukawa), *Melicope ternata* Forst. (wharangi), *Melicytus ramiflorus* Forst. (mahoe), *Litsaea calicaris* (A. Cunn.) Hook. f. (mangeao), and *Paratrophis smithii* Cheesem. A number of species, including *Pittosporum fairchildii* Cheesem. and others endemic to the Three Kings, were represented only by a few or by single individuals.

Although these were in many cases flowering or fruiting vigorously upon our arrival, seedlings or young plants were entirely absent, except in the case of *Melicope ternata,* to which reference is made above. Individuals appeared in most cases to be fully mature, and exhibited much dead wood, probably as the result both of extreme age and of direct attack by goats. It was particularly noticeable that on these highly-palatable trees foliage existed only above the reach of goats, which are capable of browsing at a maximum height of approximately five feet.

A number of trees were ring-barked, an arresting example being a large *Hiemerliodendron brunoniana* (Endl.) Skottsb. (bird-catching tree), which fell on the northern cliff face during an easterly storm in April. The trunk had been weakened and opened to fungal and insect attack by constant ring-barking, and the surrounding forest had been thinned so that the tree was open to the full force of the wind.

Briefly, the tendency of *Leptospermum ericoides* communities to predominate in the present vegetation may be attributed to two principal modifying factors: first, the widespread establishment of *Leptospermum* after Maori occupations, and second, the selective effect of grazing and browsing by a considerable goat population during the following period.

Succession would be expected to have been towards climax forest at the end of the periods of Maori clearing. The influence of goats, following upon regeneration by *Leptospermum*, had resulted in the establishment of a predominating subclimax community, the *Leptospermum ericoides* forest association.

Had goats remained on the island, remnants of the primary forest must ultimately have given place to the all-invading *Leptospermum ericoides* communities. Plants incapable of withstanding grazing or browsing, including the seedlings of most woody plants and many herbs, had already been wholly or partly suppressed for a long period; obvious maturity or old age suggesting forcibly the impermanence of primary forest remnants.

(b) Animal Elements.

Observations and collections by several zoologists indicate the indirect influence of the goat population upon other animals in the communities through modification of the vegetation. The opportunity is taken in this paper to discuss published material and certain additional observations, which may be significant should future analyses of the animal elements be made. Valuable comparison will be possible with animal elements on other islands of the group, when these have been fully examined, as has been indicated by Baylis (ibid.) with respect to the vegetation.

(1) Birds.

The island has a greatly impoverished land bird fauna. The following table compares the resident indigenous forest-inhabiting species of Great Island with those of three other offshore islands or groups (Buddle, 1941 and 1946; Turbott, 1940 and 1947).

Fig. 7. E. Quadrat I, 6th May, 1946: north-eastern section, showing (foreground) *Cordyline australis*, (centre right) *Melicope ternata*, and (left) young *Leptospermum ericoides* near north-east corner.

Fig. 8. F. Quadrat I, 29th April, 1946: eastern section, showing tall *Leptospermum ericoides* forest; ground layer with dense *Carex* spp. and associated plants.

	Little Barrier Island (7000 acres)	Hen Island (1175 acres)	Poor Knights Islands (480 acres)	Great Island (1000 acres)
Apteryx australis Shaw, kiwi	+			
Hypotaenidia philippensis (L.), banded rail	X		X	X
Porzana tabuensis (Gm.), spotless crake			X	X
Hemiphaga novaeseelandiae (Gm.), pigeon	X	X		
Nestor meridionalis (Gm.), kaka ..	X	X		
Cyanoramphus novaezelandiae (Sparrm.), red-fronted parakeet	X	X	X	X
C. auriceps (Kuhl), yellow-fronted parakeet	X	X		○
Ninox novaeseelandiae (Gm.), morepork	X	X		X
Halcyon sanctus V. & H., kingfisher ..	X	X	X	X
Acanthisitta chloris (Sparrm.), rifleman	X			
Pseudogerygone igata (Q. & G.), grey warbler	X	X		○
Petroica macrocephala (Gm.), tit ..	X	X		
Miro australis (Sparrm.), robin	X			
Rhipidura fuliginosa (Sparrm.), fantail ..	X	X		X
Mohoua ochrocephala (Gm.), whitehead	X			
Zosterops lateralis (Lath.), silvereye ..	X	X		
Prosthemadera novaeseelandiae (Gm.), tui	X	X		○
Anthornis melanura (Sparrm.), bell bird	X	X	X	X
Notiomystis cincta (Du Bus), stitch bird	X			
Creadion carunculatus (Gm.), saddleback	○	X		

+ probably from introduced stock. ○ recorded formerly.

Continued modification of the vegetation by goats would appear to be primarily responsible for the small number of species now occurring on Great Island. The other islands listed are essentially unmodified, being clothed in mixed forest or scrub.

On the Poor Knights group (approximately 480 acres) the vegetation is a mixed coastal scrub with a small amount of coastal forest, which would tend to some degree to limit such species with special food requirements as *Nestor meridionalis* (kaka) and *Hemiphaga novaeseelandiae* (pigeon) (Turbott, ms.). The small populations which the area could support may also have resulted in the elimination of species through factors of genetic composition (Huxley, 1942; Mayr, 1942). The small number of species and environmental conditions of the Poor Knights are closely paralleled on South West Island (approximately 70 acres), an unmodified smaller member of the Three Kings group (Buddle, 1948).

Such limits of vegetation and area would not appear to have affected the original bird fauna of Great Island. It will be seen that the island approximates in area to Hen Island, which has a much greater number

of species. The original vegetation is considered by Baylis (1948) to have been a "mixed coastal or semi-coastal forest with the same dominant species as may be found on the mainland and other coastal islands."

In August, 1887, Cheeseman (1888) observed two forest-inhabiting species, *Prosthemadera novaeseelandiae* (tui) and *Pseudogerygone igata* (grey warbler), which are now absent*; and a further now unrepresented species, *Bowdleria punctata* (Q. & G.) (fern-bird), an inhabitant of scrub and swamp vegetation on the mainland. Cheeseman also noted *Zosterops lateralis* (silvereye), a species recorded recently only as a straggler. Athough Cheeseman only lists these species, giving no indication of their breeding status, it seems probable that they were in fact resident at the time of his visit.

Two of these species, *Pseudogerygone igata* and *Zosterops lateralis*, were also recorded by Cheeseman on South West Island in the spring of 1889 (Cheeseman, 1891), but are apparently now absent (Buddle, 1948). Their possible extinction on this adjacent unmodified island would suggest that the persistence of the smaller population might have depended upon an occasional influx from Great Island.

A further species, *Cyanoramphus auriceps* (yellow-fronted parakeet) was recorded as late as 1934, but not during recent visits (Turbott and Buddle, 1948).

These species have apparently succumbed as the result of the continued influence of goats upon the vegetation. It may be suggested that others, such as *Hemiphaga novaeseelandiae* (pigeon) and *Nestor meridionalis* (kaka), were originally present, but were destroyed as food or through modification of the vegetation during the Maori occupations.

It would not have been beyond the powers of dispersal of most of the now unrepresented species to recolonise Great Island from the mainland, approximately thirty-five miles distant, but with the progressive impoverishment of the vegetation by goats such re-establishment would have been impossible. It may be noted that Watt (1947) records *Hemiphaga novaeseelandiae, Pseudogerygone igata, Bowdleria punctata* and *Zosterops lateralis* as numerous on the immediately adjacent mainland. Mr. A. H. Watt, of Paua, has informed me (in litt.) that in 1948 one individual of *Prosthemadera novaeseelandiae* appeared there as a straggler; this and other forest-inhabiting birds are established approximately sixty miles to the south, beyond the low-lying narrow northern isthmus.

Populations of the species of indigenous land birds at present occurring on Great Island may also be considered to reflect strongly the modificaton of the vegetation. Only one species, *Anthornis melanura*† (bell bird) has a high population density, being abundant throughout the

* Johnson (1946) has published a record of *Prosthemadera novaeseelandiae* as having been observed on 1st January, 1945. Major M. E. Johnson has informed me that, after further observation on subsequent visits, he regards his identification as probably mistaken.

† Described as subsp. nov. in this series by Falla (1948).

Fig. 9. G. Quadrat II, 27th April, 1946: area of north corner (peg and flag centre left), showing *Leptospermum ericoides* forest; on ground layer, turf and scattered *Carex* spp.

Fig. 10. H. Quadrat II, 27th April, 1946; north-eastern side of quadrat near north corner peg. Young *Leptospermum ericoides* (right); scattered *Carex* spp., *Scirpus nodosus* and turf on forest floor.

Leptospermum ericoides forest. Although flowers bearing nectar are few, this particularly adaptable species has evidently become adjusted to a predominantly insectivorous diet.

Of the remaining indigenous birds, the numbers of *Anthus novaeseelandiae* (Gm.) (pipit) may be placed following, but considerably below, those of *Anthornis melanura*. This species occupies a special niche on Great Island in that it penetrates the characteristic parklike forest, habitually perching on the trees and feeding on the more open parts of the forest floor. It is found also on the grassland area, and on the shore, which is its normal habitat on densely forested islands.

Ninox novaeseelandiae (morepork) is fairly abundant, such food as lizards, insects, and the considerable numbers of *Anthornis melanura*, being plentiful.

There is a marked contrast in the population density of the five other indigenous forest-inhabiting species. *Cyanoramphus novaezelandiae* (red-fronted parakeet) and *Halcyon sanctus* (kingfisher) occur in moderate numbers only, and *Rhipidura fuliginosa* (fantail) is represented by a small population of probably not more than fifty for the whole island (approximately 1,000 acres).* This estimated population for the last species may be compared directly with my count of nine breeding pairs occupying seventy-five acres of mixed forest on Hen Island, a density representing 240 per 1,000 acres (Turbott, 1940).

Of the two forest floor species, *Hypotaenidia philippensis* (banded rail) occurs in small numbers, and *Porzana tabuensis* (spotless crake) has been recorded (Turbott and Buddle, 1948) only on two occasions.

Nine species of naturalised passerine birds from the mainland have become established on Great Island: *Fringilla coelebs L.* (chaffinch), *Carduelis cabaret* (P.L.S. Mull.) (redpoll), *Carduelis carduelis* (L.) (goldfinch), *Passer domesticus* (L.) (house sparrow), *Emberiza citrinella* L. (yellowhammer), *Turdus ericetorum* Turt. (song thrush), *Turdus merula* L. (blackbird), *Prunella modularis* (L.) (hedge sparrow) and *Sturnus vulgaris* L. (starling). Most of these penetrate more deeply into the open *Leptospermum ericoides* forest than into mixed forests on the mainland. It would be expected that they might, under these conditions, tend to predominate over indigenous species, but all, with the exception of *Turdus merula*, are represented by small populations. Although, with widespread modification, competition might be expected to have been sharpened to an even greater degree than is usual on small islands (Mayr, 1942), none of these species would appear to have exerted a marked influence upon the indigenous birds. *Turdus merula*, which has advanced into a wide range of habitats, including forest, throughout New Zealand, is only moderately plentiful; this species may, as Buddle (1941, 1948) suggests in referring to the Poor Knights and South West Island, compete to some degree for food with the indigenous rails.

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* Turbott and Buddle (1948) discuss the effect of these small numbers upon the establishment of a mutant element in the population of *Rhipidura fuliginosa*.

A species of *Synoicus** (brown quail) is present in moderate numbers in more open parts of the forest, where insects and fruits of grasses and sedges provide an abundant food supply not comparable with that of any other species.

It should be noted that the above references to population densities are based upon estimates: it was unfortunately not possible to carry out census work which would have permitted of direct comparison with the mainland or other islands (Turbott, 1940).

Comparison of total population densities in various habitats with Great Island would also be of value. My observation would suggest a much lower total density in forest on Great Island than on unmodified offshore islands (Turbott, 1940, 1947 and ms.).

Factors which appear to have controlled the number of species and populations of land birds on Great Island may be stated briefly. The primary influence is considered to have been that of goats through the continued modification of the vegetation. Of predatory birds, numbers of *Ninox novaeseelandiae* (morepork) would not appear to predominate in relation to other species; *Circus approximans* Peale (harrier) is represented by not more than six individuals probably ranging freely over the group. The small populations of the naturalised species would appear insufficient to have markedly influenced the indigenous species through competition.

The status of two of the present indigenous species is of particular interest. *Cyanoramphus novaezelandiae* (red-fronted parakeet) appears to have decreased considerably in numbers since 1934 (Turbott and Buddle, 1948). *Porzana tabuensis* (spotless crake) is extremely rare on Great Island, although forming a vigorous, breeding element on South West Island (Buddle, 1948); on this unmodified island it has the same status as on the Poor Knights (Buddle, 1941, 1946). The factors indicated above have brought about a particularly marked reduction in the numbers of both species, *Porzana tabuensis* having almost reached the point of extinction.

In the case of the sea birds, the presence of goats has undoubtedly to some degree affected the area available for nesting to various petrels and to *Larus novaehollandiae* Steph. (red-billed gull), which breed on Great Island in large numbers. Three of the five known species of breeding petrel, *Puffinus gavia* (Forst.) (fluttering shearwater), *Pelecanoides urinatrix* (Gm.) (diving petrel) and *Pterodroma macroptera* (Smith) (grey-faced petrel) occur in considerable numbers, but all tend to be restricted to cliff faces and other areas not invaded by dense ground vegetation. The distribution of breeding petrels must also be affected directly by general hardening of the soil and by trampling. On unmodified islands the burrows of these and other species, although in many cases in more or less compact colonies, occur throughout the forest or scrub.

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* Possibly a species of *Synoicus* indigenous to New Zealand rather than the naturalised *Synoicus ypsilophorus* (Bosc.) (Turbott and Buddle, 1948).

Fig. 11. J. Quadrat II, 27th April, 1946: south-western side, over south corner peg (left foreground). *Melicope ternata* to right. Dense floor -covering of *Carex* spp.

Fig. 12. K. Quadrat III, 28th April, 1946: north-western side over west corner peg (foreground). *Zoisia* sward with *Scirpus nodosus; Leptospermum ericoides* (height five feet) in north corner. In distance *L. ericoides* forest on northern side of Tasman Valley.

The large colonies of *Larus novaehollandiae* have also been restricted to areas relatively free from disturbance by goats, although reduction of the vegetation would have provided open nesting places not originally available.*

Finally, in considering factors affecting both land and sea birds it is necessary to take into account the complete absence of naturalised predatory mammals, cats, rats and mustelids being absent from this and other members of the Three Kings group.

(2) Invertebrates.

As the result of the work of Powell (1935 and 1948) the land molluscs of Great Island are better known than other invertebrate groups. This author attributes the extremely limited range of the large herbivorous snail *Placostylus bollonsi* Suter primarily to the clearing of the original forests by Maori inhabitants. The population has subsequently been restricted, and probably reduced, to three small isolated colonies by the direct trampling effect of goats and the limited range of suitable food plants. Two colonies occur on rocky areas associated with small groves of large-leaved trees, the fallen leaves providing a normal food-supply. The third exists under apparently less favourable conditions on a rocky seaward cliff face beneath a practically impenetrable band of *Myoporum laetum* scrub. Powell (1948) describes members of this isolated colony as representing a new subspecies, considering that the smaller adult size has developed in adaptation to the restricted diet.

Powell (ibid.) lists eight further species of land molluscs, *Egestula gaza* (Suter) being abundant on the forest floor in *Leptospermum ericoides* forest.

The remaining terrestrial invertebrates are inadequately known. During the Expedition I collected material representing a number of groups, which in several cases await examination.

Beating in *Leptospermum ericoides* shrubland produced a restricted number of species which were in no case markedly abundant: these included leaf-hoppers and a pentatomid bug (Hemiptera); beetles (Coleoptera); and mites and spiders (Arachnida). Mr. A. E. Brookes, who has kindly informed me of the results of his preliminary examination of beetles from the island, considers that the affinities of those obtained by beating are with mainland species generally found in mixed forest, rather than in *Leptospermum* communities.

On the ground in *Leptospermum ericoides* forest, carabid and tenebrionid beetles were particularly common under fallen branches, stones and in drifts of boulders.

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* Observations since the goats were destroyed indicate that the colonies of *Larus novaehollandiae* on the slopes above North West Bay and South East Bay have expanded considerably, although herbaceous and shrubby vegetation is already increasing on these areas (Turbott and Buddle, 1948).

The pupal cases of a *Porina* sp.* (Lepidoptera) were of frequent occurrence, the adults appearing at light in the evenings. A species of *Odontria* (Coleoptera) also came fairly frequently to light. The apparently considerable population of both of these insects is possibly related to the sedges, grasses and herbs of the ground layer, which would provide abundant food for the subterranean root-feeding larvae.

As indicated above, dead and dying wood was plentiful throughout the *Leptospermum ericoides* communities and especially in the climax forest remnants. This had been heavily attacked by wood-boring weevils and other beetles, and, in several cases observed, by colonies of termites (Isoptera).

(c) Examination of stomach contents of goats killed, and observations on food habits.

There were few opportunities during the Expedition to investigate stomach contents, or to observe goats feeding, mainly because of the dispatch with which the work of destruction was carried out. Within three weeks of our arrival the population had been reduced to approximately twenty, and these were particularly wary.

Stomachs examined with the help of Mr. L. C. Bell indicated that goats were feeding largely upon grasses, sedges (particularly *Carex*) and herbaceous plants obtained by grazing. A few fragments of leaves of *Myoporum laetum* were recorded in stomach contents.

After high winds two stomachs examined contained a large proportion of leaves, including those of *Melicytus ramiflorus, Litsaea calicaris* and *Metrosideros excelsa,* and pieces of a large lichen common on *Leptospermum ericoides.* Material of this kind had been blown to the ground in considerable quantity.

Goats were observed grazing on both forest floor and grassland, moving about in typically capricious manner, but were on no occasion seen attempting to browse. Cropped sedges (*Carex* spp. and *Scirpus nodosus*) were observed, but the direct effect of grazing upon other herbaceous plants was not apparent.

As already indicated, foliage was absent on the remaining highly-palatable trees at levels which goats could reach, i.e., approximately five feet. A *Corynocarpus laevigata* Forst. (karaka) was observed upon which a number of lower leaves had been bitten in half, goats having stood upon their hind legs to browse upon the foliage.

It is of interest in relation to palatability that experiments by Cunningham and Hopkirk (1945) have shown the leaves of *Myoporum laetum* to be poisonous to sheep; a similar effect is recorded for cattle, horses and pigs.

(d) Mechanical effect of goats.

The principal effect of goats in the communities is through modification of the vegetation as a function of food habits.

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* sp. nov. (Salmon, 1948).

Fig. 13. L. Quadrat III, 5th May, 1946: entire quadrat from approximately twenty yards beyond north-western side; west corner peg in right middle distance, east corner peg centre left. In distance, prostrate *Leptospermum ericoides* scrub on southern side of Tasman Valley.

Fig. 14. M. Quadrat III, 28th April, 1946: diagonally across quadrat from south-east side to west corner peg (left middle distance); showing *Scirpus nodosus* and wind-swept *Leptospermum ericoides* shrubland. The ground drops steeply to the south-western cove from the skyline.

As distinct from this coactive effect, mechanical reaction is evident to a certain degree in hardening of the soil, more particularly on the crests of steep seaward slopes.

As recorded above, the constant movement of the goat population is regarded by Powell (1948) as a factor in preventing any increase or spread of the colonies of *Placostylus bollonsi*. This purely mechanical action has probably also been effective in the case of a number of other ground-living animals.

Sea bird colonies are also considered to have been affected by trampling and hardening of the soil.

CHOICE OF LOCALITIES, AND GENERAL DISCUSSION OF QUADRATS.

The following sections of this paper consist of a detailed description, as far as possible in quantitative terms, of the vegetation of three permanent quadrats, which were established to demonstrate the course of potential changes in the plant covering.

An important consideration in planning quadrats was that the time available on this inaccessible island must tend to be short. Accordingly, some care was taken to locate the quadrats within convenient distances of landings and reference points. The description of the vegetation is in a form suitable for immediate reference, depending chiefly upon quadrat charts, accompanied by photographs and in two quadrats by supplementary lists of species.

Otherwise the choice of quadrats was influenced by two aspects of the present status of the vegetation:

(1) The destruction of the goats took place before the complete extinction of the primary forest remnants, and consequently in time to allow of the possibility that a climax forest originating from this stock would replace the widespread *Leptospermum ericoides* communities. It would be expected also that certain species with effective means of dispersal might colonise Great Island from other islands of the group, the plants of which are described in papers in this series (1948) by Baylis, Buddle and Oliver; and that colonisation may be possible from the adjacent mainland.

Quadrats I and II, consisting of *Leptospermum ericoides* forest, including, or within known distance of, groves of mixed forest trees, were chosen to indicate the course of regeneration in the more immediate neighbourhood of the climax forest remnants.

Quadrat I, situated in a moderately deep valley, is necessarily relatively large—40 metres square—in order to include groves of climax forest trees, together with a representative area of adjacent tall *Leptospermum ericoides* forest.

It is worth recording that two additional climax species, *Corynocarpus laevigata* and *Hiermerliodendron brunoniana*, are present in a valley within 50 yards of the quadrat to the north.

Quadrat II is situated in the upper portion of the same valley, where the ground is drier. Unlike Quadrat I, this quadrat represents a relatively uniform plant covering, and is accordingly only 15 metres square. The vegetation, consisting of uniform *Leptospermum ericoides* forest of moderate height, is perhaps more characteristic than that of Quadrat I of the greater part of the island. The quadrat is approximately 75 yards from the climax forest trees of Quadrat I, and was chosen with a view to demonstrating regeneration in *Leptospermum ericoides* forest separated by at least a moderate distance from the nearest forest remnants.

(2) The future of the Tasman Valley *Zoisia* sward will be of particular interest, especially in view of the suggestion (Baylis, 1948) that it was in the course of invasion before the destruction of goats by *Leptospermum ericoides* shrubland.

Quadrat III is situated in *Zoisia* sward, bordering on hummocky patches of low *Leptospermum ericoides*. A quadrat 15 metres square was sufficient to include typical patches of *Leptospermum ericoides* shrubland together with adjacent sward. On this quadrat changes in the sward will be readily observed, and the quadrat will be interesting in demonstrating the potentialities for invasion of the *Leptospermum ericoides* shrubland in the absence of goats. The effect of wind, as reflected in, the growth-form of the adjacent *Leptospermum ericoides* shrubland and prostrate scrub, may be of some importance in controlling the vegetation on this quadrat.

LOCATION OF QUADRATS.

(1) *Marks.* Each quadrat is a square, the corners being marked by a half-inch galvanised iron pipe driven well into the ground and surrounded by a strongly-built cairn of large stones. For purposes of observation a rough standard bearing a white flag was fitted into every pipe, but these will probably not remain intact for more than six months. (Figs. 9 and 12).

The corner pegs of the quadrats should not be confused with the wooden pegs, painted white and numbered 1-4, which were used to mark seedlings in or near Quadrat I.

(2) *Directions for locating quadrats. In order to find the position of the quadrats it will be necessary for future observers to take with them a prismatic compass.* The bearings given below are all magnetic.

Quadrats I and II are close together in the first valley to the east of the castaway depot,* after crossing the saddle between North West Bay and South East Bay (Fig. 1).

Quadrat I is reached by walking to a prominent inland rock on the first ridge to the north-east across the saddle between North West Bay and South East Bay; the bearing of this rock over the centre of the depot is 34°. (It appears probable that actively growing *Leptospermum ericoides* will tend increasingly to obscure visibility from the depot

* It is anticipated that the depot will survive as a recognisable reference point for a number of years.

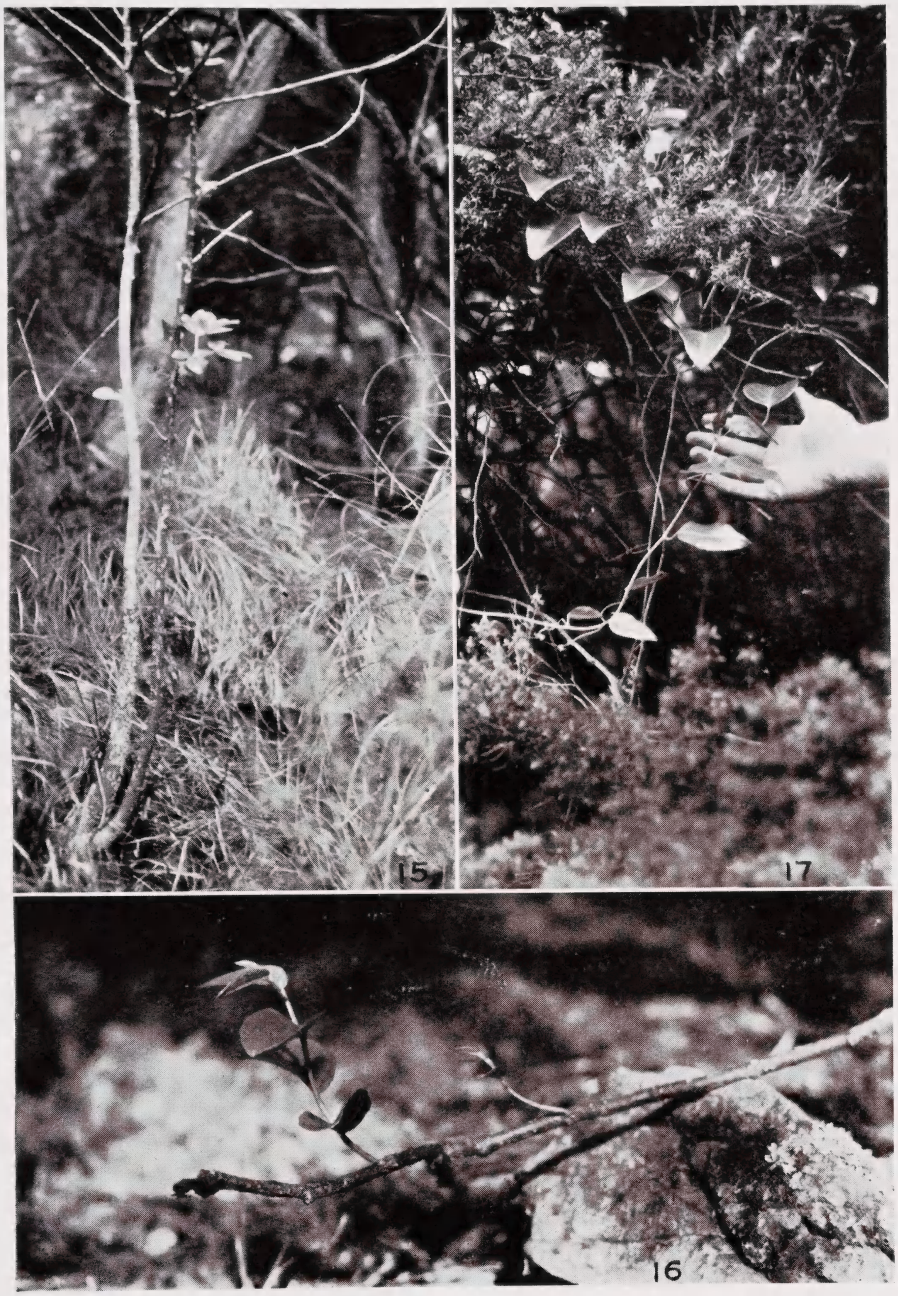

Fig. 15. *Melicope ternata* six feet in height browsed and ring-barked by goats, Quadrat I, 25th April, 1946.

Fig. 16. New shoots near ground level on *Paratrophis smithii* after destruction of goats, Quadrat I, 6th May, 1946.

Fig. 17. New shoot four feet from ground on *Tetrapathaea tetrandra*, clinging to *Leptospermum ericoides* in lower part of photograph. Note old shoot nipped off by goats against palm of hand. Quadrat I, 6th May, 1946.

itself.) Upon reaching the rock, the observer should move round to the left until above it; then, at a bearing of 65°, walk approximately 85 yards to the south-west corner peg of the quadrat. The peg is placed in a pocket amongst rocks and is at present adjacent to a grove of mixed trees (see plan of quadrat, Fig. 20). From this peg the bearing of the west side of the quadrat is 6°.

Quadrat II is approached from above the same inland rock as in the directions for Quadrat I. From here at a bearing of 350° a distance of approximately 80 yards leads to the west corner peg of the quadrat. From the peg, which is on a moderate slope, the bearing of the N.W. side of the quadrat is 39°.

Quadrat III is some distance from the castaway depot, being situated in the area covered at present by grassland on the south side of Tasman Valley (Fig. 1).

The quadrat is near the lowest point of a saddle (Fig. 2) close to the south-west coast of the island. This low saddle is clearly outlined from any point on the ridge to the south-west of the depot, but may be identified exactly as bearing 167° from a prominent rounded rock which stands out on this ridge. After crossing the Tasman Valley to reach the lowest point of this saddle, the observer will find as a landmark a yellowish weathered rock, about six feet high, on the crest of the steep seaward slope above the south-western cove. From this rock walk back for approximately 95 yards at a bearing of 334° to reach the south corner peg of the quadrat. The bearing of the south-east side of the quadrat from this peg is 14°.

VEGETATION OF THE QUADRATS.

Method of description. Field identifications have been checked by specimens referred in the case of vascular plants to Dr. G. T. S. Baylis, of lichens to Dr. H. H. Allan, and of mosses to Mr. G. O. K. Sainsbury. Specimens from the quadrats have been placed in the herbarium of the Auckland Museum.

The vegetation of the quadrats is described by means of (1) the quadrat charts, together with supplementary lists of physiognomic species in the case of Quadrats II and III; (2) photographs showing certain portions of the quadrats.

The degree of quantitative detail represented by the charts was governed by the time available in the field. The quadrats had necessarily to be of relatively large area in order to include representative areas of forest or shrubland, and it was correspondingly impossible to attempt quantitative description of the ground layer over the full area of the quadrats. Thus in the ground layer physiognomic species only are indicated, according to distribution.

Had more time been available, ground layer quadrats of one or a few metres could with advantage have been established.

Non-physiognomic herbs which occurred on the quadrats, especially on the forest floor in Quadrats I and II, are omitted from my description; species falling under this category being, in general, those referred to as "common" or "abundant" by Baylis (1948) and Oliver (1948).

The vertical structure of the vegetation is indicated by the photographs alone; the construction of profile diagrams was not undertaken.

The two charts for Quadrat I accompanying this paper have been reconstructed from a field chart, upon which both canopy and ground layer were plotted. In the field, position and extent of foliage of the canopy trees, and distribution of the ground layer species, were indicated by the initial letters of generic and specific names; in plotting the canopy, letters of varying size were used to indicate the extent of the individual crown.

The procedure in plotting was to record each strip of two metres passing from side to side of the quadrat, the ends and mid-points of successive strips being marked by a temporary flag.

A similar procedure was adopted in recording the less varied vegetation of Quadrats II and III.

Quadrat I.

Figs. 20 and 21 (charts); and Figs. 3 to 8, and 15 to 17 (photographs).

Of the charts for Quadrat I, Fig. 20 represents, in plan, the position and status of every individual woody plant. Fig. 21 indicates the distribution of physiognomic species forming the ground layer. The following brief general account completes the description of the quadrat.

The forest of Quadrat I, and on all parts of the island accessible to goats, may be divided primarily into two main layers, the canopy and the forest floor. The canopy layer is regarded as that comprising the dominant tall tree, *Leptospermum ericoides*, of height 20 to 30 feet, the growth-form of which is high-crowned; and the scattered climax trees on which foliage is present only above five feet, the approximate browsing level reached by goats.

The climax forest trees for the most part form a conspicuous element in the canopy; but in some cases individuals may be lower than, and to some degree overshadowed by, the tall *Leptospermum ericoides*, these also being regarded as part of the canopy. The heights vary from *Litsaea calicaris* reaching 25 feet, to *Pittosporum fairchildii*, 15 feet.

Between the canopy and the ground layer the forest is characteristically open and free of undergrowth, except for scattered shrubs, and young or low-growing plants, regarded as unpalatable to goats (Fig. 20B). The commonest species is *Melicope ternata*, individuals ranging in height from 3 to 36 inches.

In the north and north-east portions of the quadrat there are two aggregations of regenerating *Leptospermum ericoides* up to 15 feet in height, filling a gap in the canopy where large trees have fallen.

As indicated by the charts and photographs, the forest floor under tall *Leptospermum ericoides* is clothed in a dense ankle- to knee-deep carpet of the two species of sedge, *Carex testacea* and *Carex virgata*; but is practically bare, with a deposit of somewhat dry leaf-mould, in

Fig. 18. N. Quadrat III, 28th April, 1946: south-eastern side of quadrat, showing dense hummock of *Leptospermum ericoides* (height two feet) near south corner; *Scirpus nodosus;* and *Zoisia* sward.

Fig. 19. Quadrat III, 1st January, 1948: from approximately the same position and angle as Fig. 18, showing abundant seed heads on sward.

Photo. G. T. S. Baylis.

the heavy shade of the grove of mixed trees in the south-west corner (Figs. 3 and 4), and under the dense canopy of young *Leptospermum ericoides* to the north.

The ground is rocky in the south-west and north-west corners of the quadrat, and along the dry watercourses, providing in damper areas a characteristic habitat for the tall-growing fern *Pteris comans* Forst. f.

It may be noted finally that the fern *Doodia media* R. Br. differs markedly according to amount of shade and moisture, becoming much reduced in size and being red in colour under openings near the northern margin.

Regeneration observed during the Expedition. Destruction of goats was proceeding throughout the period of field work on the quadrats, and it is probable that after 25th April, when large numbers of goats had already been killed, there was little normal feeding by the remaining frightened animals.

From 1st May all members of the expedition were impressed by the vigorous growth of young grass and herbs, and of soft new shoots which appeared at a low level on several species. This was particularly apparent in the case of *Cordyline australis* (cabbage tree), upon which growth of new shoots occurred near the base of the trunk.

On Quadrat I, low branches of *Paratrophis smithii* were bearing young shoots by 6th May (Fig. 16) ; and regrowth was vigorous on the vine of *Tetrapathaea tetrandra* (DC.) Cheesem. just outside the north-west corner of the quadrat (Fig 17).

On 6th May two seedlings of *Colensoa physaloides* (A. Cunn.) Hook. f. three inches high were recorded on the north side of the quadrat, where the edge of the quadrat intersects the dry stream bed.

Most species of the climax forest remnants on the quadrat were producing abundant seed during April and May.

Numerous small seedlings had appeared by May in the neighbourhood of the grove of mixed trees and vines of *Clematis indivisa* Willd. in the south-west corner of the quadrat, but in most cases could not be identified in the field.

Of these, two seedlings which appeared almost certainly to be *Litsaea calicaris,* and two young plants of *Melicope ternata,* were marked with numbered pegs of durable wood painted white. The pegs were, in every case, placed one foot to the north with the number facing the specimen (Fig. 20). Seedlings marked thus were:—

Peg number

1. *Melicope ternata,* height 6 inches.
2. *Litsaea calicaris,* height 1 inch.
3. *Melicope ternata,* height 4 inches.
4. *Litsaea calicaris,* height 2 inches.

Elsewhere than on Quadrat I seedlings were observed in the neighbourhood of groves of mixed trees, but were in most cases too small for identification. Mr. L. C. Bell, in examining a heavily-fruiting specimen of *Sideroxylon novo-zelandicum* (F. Muell.) Hemsl. (tawapou) above South East Bay shortly before our departure, found numerous seedlings which had just appeared through the leaf-mould.

Quadrat II.

Fig. 22 (chart); and Figs. 9 to 11 (photographs).

On the chart both canopy and forest floor are represented, the whole having been reduced to diagrammatic form indicating only certain important aspects of the vegetation. Less time was spent in field work on this quadrat than on Quadrat I, the vegetation being relatively uniform, and essentially of the same composition as that part of Quadrat I consisting of *Leptospermum ericoides* forest.

In general, the canopy is lower and more open than in Quadrat I. The canopy layer is formed by 46 individual *Leptospermum ericoides*, of an average height of 18 to 20 feet; the trunks range in diameter from $3\frac{1}{2}$ to 8 inches. The only other species reaching the canopy is *Cordyline australis*, represented by a single individual in the extreme eastern corner, of height eighteen feet.

Three *Leptospermum ericoides* had recently fallen, leaving gaps in the canopy; in one gap larger than the others in the eastern corner a small group of young *Leptospermum ericoides* had sprung up, reaching a maximum height of six feet.

Low rounded shrubs of *Coprosma rhamnoides* are scattered over the quadrat.

The forest floor on the southern one-third of the quadrat, where the ground is damp, supports the characteristic dense sedge (*Carex testacea* and *Carex virgata*). *Carex testacea* continues towards the drier shoulder of the ridge, becoming progressively shorter and more sparse and giving place over increasing areas to a short turf of grasses, mosses and herbs.

The fern *Doodia media* is plentiful throughout the quadrat, taking on a reduced and flattened growth-form in drier conditions under the open canopy.

The following list includes the physiognomic species composing the short turf, and certain herbaceous species growing through the turf throughout the quadrat:

MOSSES.

Thuidium furfurosum (Hook. f. and W.) Jay.

GRASSES.

Oplismenus undulatifolius Beauv.
Echinopogon ovatus (Forst. f.) Beauv.
**Aira praecox* L.

* Introduced into New Zealand.

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Subdivisions are two metres square.

Fig. 20.

A. POSITION AND APPROXIMATE EXTENT OF INDIVIDUALS FORMING CANOPY, INCLUDING ALL TREES WITH FOLIAGE ABOVE FIVE FEET (APPROXIMATE LEVEL REACHED BY GOATS).

A formalised outline represents position and area of every crown. For *Cordyline australis* a symbol represents position only. Double outlines denote primary forest species.

Lc —*Litsaea calicaris* (mangeao).

Le —*Leptospermum ericoides* (kanuka).

—*Leptospermum ericoides*—dead, still standing.

Mr —*Melicytus ramiflorus* (mahoe).

Mt —*Melicope ternata* (wharangi).

Pf —*Pittosporum fairchildii*.

Ps —*Paratrophis smithii*.

—*Clematis indivisa*—outline includes group of roots.

—*Tetrapathaca tetrandra*—rooted outside the quadrat.

—*Cordyline australis* (cabbage tree).

B. POSITION OF INDIVIDUAL WOODY PLANTS BELOW FIVE FEET.

Symbols represent position only, except in the case of young *Leptospermum ericoides*.

—*Coprosma rhamnoides*.

—*Melicope ternata*—including young plants and seedlings.

—Ditto, exhibiting damage by goats (defoliation and ring-barking).

—*Myoporum lactum* (ngaio).

—Ditto, damaged by goats.

—*Leptospermum ericoides*, young.

1-4 —Position of young plants and seedlings marked by numbered pegs.

Arrows A-F indicate angle of photographs (Figs. 3 to 8), which are intended to be examined in conjunction with charts. Position and angle of photographs are approximate.

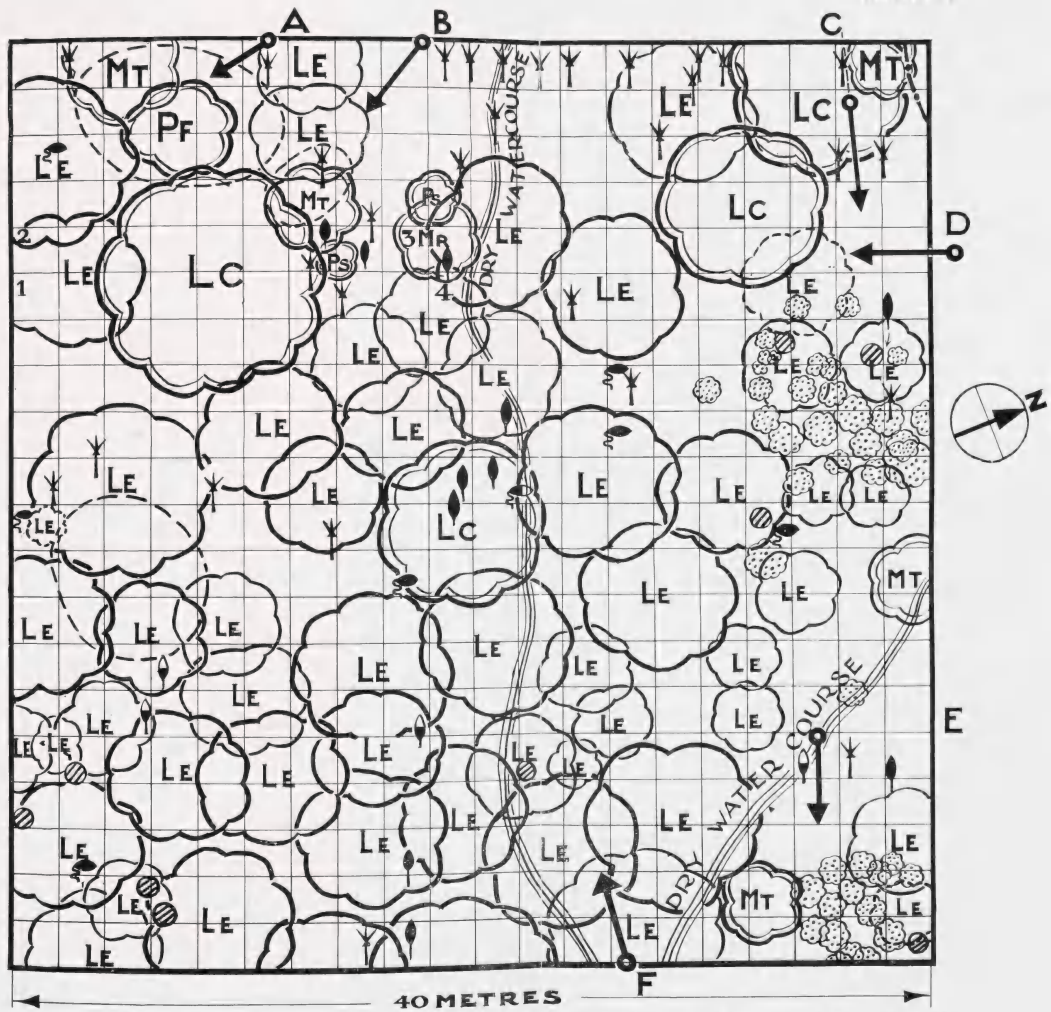

Fig. 20. PLAN OF QUADRAT I, charted 26th April to 14th May, 1946. Canopy; shrubs below level reached by goats; and seedlings of woody plants.

HERBS.

Oxalis corniculata L.
Haloragis procumbens Cheesem.
Centella asiatica (L.) Urban
Dichondra repens Forst.
Lobelia anceps L.
Wahlenbergia gracilis (Forst. f.) Schrad.
Gnaphalium collinum Lab.

Quadrat III.

Fig. 23 (chart) ; and Figs. 12 to 14 and 18 to 19 (photographs).

This quadrat is situated in typical *Zoisia* sward bordering on wind-swept *Leptospermum ericoides* shrubland.

The substratum is rocky, as over most of the Tasman Valley grassland. The ground upon which the quadrat is placed appears to be a little damper than most of the grassland area, and may represent a region of slight seepage.

The quadrat encloses part of two clumps of *Leptospermum ericoides*. That to the south is moulded by wind into a dense cushion not more than two feet high. The other, in the northern corner, is part of a patch reaching five feet in height, tall enough to have been penetrated by goats in search of shelter.

In marked contrast to the closely-cropped sward, the ground species beneath the patches of *Leptospermum ericoides* have a straggling growth-form, and even grow luxuriantly under the denser cushions, which appear to afford a certain degree of protection from goats.

Carex testacea appears in the shade of these clumps, and abundant *Scirpus nodosus* rises through the wind-shorn hummocks. The growth-form of the fern *Doodia media* is here in particularly marked contrast with that on the sward, being green in colour with loose, spreading fronds.

The following grasses and herbaceous species were recorded under the patch of *Leptospermum ericoides* in the north corner of the quadrat:

GRASSES.

Oplismenus undulatifolius Beauv.
Danthonia semiannularis R. Br.

HERBS.

Hydrocotyle novae-zealandiae DC.
Dichondra repens Forst.
Gnaphalium collinum Dab.

The remainder of the quadrat is covered by a short, even sward composed of the following lichens, mosses, grasses and herbaceous species:

LICHENS.

Cladonia floerkeana (Fr.) Somm.

MOSSES.

Thuidium furfurosum (Hook. f. and W.) Jay.
Leptodontium interruptum (Mitt.) Broth.
Campylopus introflexus (Hedw.) Mitt.

GRASSES.

Zoisia matrella (L.) Merrill
Deyeuxia crinita (L.) Zotov

HERBS.

Oxalis corniculata L.
Centella asiatica (L.) Urban
Gnaphalium collinum Lab.

The fern *Doodia media* is scattered sparsely over the open sward, assuming a reddish colour and almost a rosette growth-form in this situation.

The sedge *Scirpus nodosus* is particularly abundant on the sward, scattered irregularly throughout, either individually or in extensive colonies.

Note on regeneration observed during the Expedition. By 1st May, at which time there was practically no grazing, the sward had lost much of its close-cropped appearance. New grass shoots, springing up after heavy rain, were already taller than the other elements in the sward.

NOTES ON CHARACTERS OF GOATS.

The following observations were made on the animals destroyed. A more detailed record of sex and other characters was attempted but, unfortunately, proved impossible during shooting operations.

The population was evidently breeding successfully, a number of the animals destroyed being females with young near the end of gestation. Several kids a few days old were recorded. On 18th April, when 107 animals were destroyed on the western area, it was estimated that at least three-eighths were adult males.

The few skeletons found were insufficient to indicate any abnormally great number of recent deaths.

Colour of coat was particularly variable, ranging from black and brown to white. Combination of white and brown, and of white, brown and black, were of frequent occurrence.

Mr. L. C. Bell informs me that the animals were much smaller than those naturalised on the mainland. A young male and an adult female which I measured were 3 feet 9 inches in total length from nose to tip of tail; and the length of each horn 6½ inches. Mr. Bell examined several larger specimens, the greatest spread of horns which he recorded being 14 inches.

ACKNOWLEDGMENTS.

I wish to express my appreciation of the help which I received in the field from the leader of the Expedition, Mr. L. C. Bell, Field Officer, Wild Life Branch, Department of Internal Affairs; and from the other members of the party, Messrs. M. and B. Chaney and B. Meachen. Thanks are also due to Captain Cole and members of the crew of the "New Golden Hind," who succeeded under particularly stormy conditions in re-embarking the party without loss to the valuable collections made on the island.

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Subdivisions are two metres square.

Fig. 21.

DISTRIBUTION OF HERBACEOUS SPECIES FORMING GROUND LAYER. Only species regarded as physiognomic are indicated.

—*Carex testacea*: with *Carex virgata* scattered throughout (Sedges).

—*Dichondra repens*.

—*Doodia media*.

—*Oplismenus undulatifolius*, generally in association with *Echinopogon ovatus* (Grasses).

—*Pteris comans*.

—*Scirpus nodosus* (Sedge).

—Patches of turf, consisting of mosses; *Echinopogon ovatus* and other grasses; and less abundantly the herbs *Oxalis corniculata*, *Centella asiatica* and *Gnaphalium collinum*.

Arrows A-F indicate angle of photographs (Figs. 3 to 8), which are intended to be examined in conjunction with charts. Position and angle of photographs are approximate.

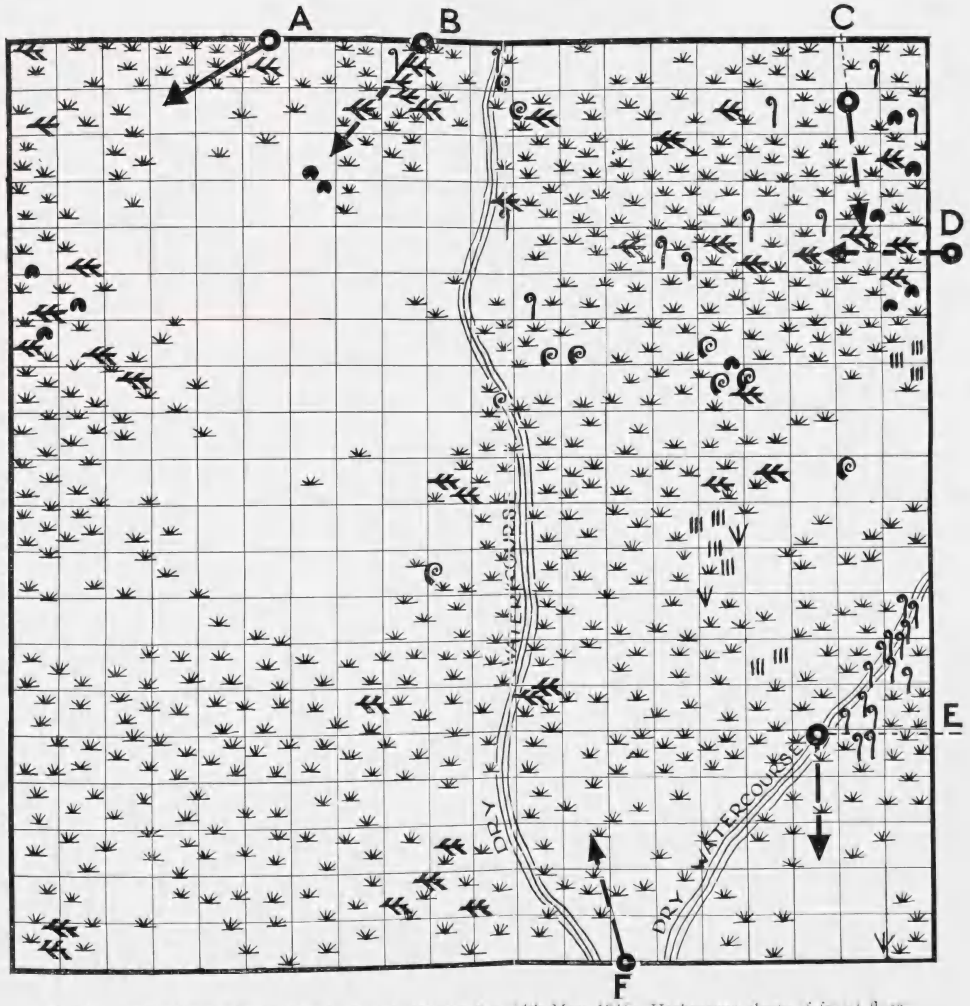

Fig. 21. PLAN OF QUADRAT 1, charted 26th April to 14th May, 1946. Herbaceous plants of forest floor.

Dr. G. T. S. Baylis has kindly identified my plant material from the quadrats, and discussed this paper helpfully at all stages; he has permitted me to refer in some detail to the manuscript of his paper on the vegetation.

Dr. H. H. Allan has kindly identified specimens of lichens, and Mr. G. O. K. Sainsbury of mosses.

I am grateful to Mr. A. W. B. Powell, Dr. W. R. B. Oliver and Major G. A. Buddle for permission to refer to their manuscripts, and to Dr. K. A. Wodzicki for allowing me to examine the manuscript of his report. In the discussion of birds of the island, reference has been made to the manuscript of my joint paper with Major Buddle.

I am indebted to Mr. P. C. Bull for permitting me to compare my observations on relative populations of bird species with his estimates made during the Auckland Museum Expedition in H.M.N.Z.S. "Arbutus" (November-December, 1945).

Finally, I have received valuable assistance from Miss B. E. G. Molesworth and Mr. R. C. Cooper, of Auckland Museum, in botanical aspects of this study.

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APPENDIX

The vegetation of Great Island has been examined subsequently during visits to the Three Kings in January, 1947, and again in December, 1947-January, 1948, in Major M. E. Johnson's yacht "Rosemary" (Baylis, 1948; Buddle, 1948). On 31st December, 1947, and 1st January, 1948, Dr. G. T. S. Baylis spent a few hours ashore, and was able to re-examine briefly Quadrat III.

I am indebted to Dr. Baylis for his photograph (Fig. 19) and for the following information on this quadrat.

On the sward, grasses still have the low-growing habit but have grown freely, producing abundant seed heads. *Zoisia matrella* is still dominant, but *Deyeuxia crinita*, *Aira praecox* and *Aira caryophyllea* L. occur in some quantity. *Gnaphalium collinum* forms considerable patches.

Adjacent to the northern clump of *Leptospermum ericoides*, seedlings of this species are scattered plentifully, being at present an inch or two above the level of the *Zoisia*. It would appear that in the presence of goats, any seedlings of *Leptospermum ericoides* appearing on the sward had been suppressed by close grazing, and to some degree by trampling. On the forest floor the more selective feeding habits of the goats, and probably shelter provided by the ground layer, would appear to have been effective in enabling seedlings of this species to grow freely.

Changes in the vegetation up to 1st January, 1948, are discussed by Baylis (1948) in an appendix to his paper.

The quadrats have been examined more recently by the writer, with the assistance of Mr. L. C. Bell, during a brief visit on 6th October, 1948. Results of this visit will appear in a future paper.

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Fig. 22.

PLAN DIAGRAM OF QUADRAT II, 26th April to 14th May, 1946. The quadrat is uniformly covered by crowns of mature *Leptospermum ericoides* which are not plotted.

A. WOODY PLANTS OTHER THAN MATURE *LEPTOSPERMUM ERICOIDES*.

—*Cordyline australis*.

—Group of young *Leptospermum ericoides*.

—*Melicope ternata* (2 feet high).

—*Myoporum laetum*—young plant (outside the quadrat).

NOTE: *Coprosma rhamnoides* not plotted (see description in text).

B. GROUND LAYER: general distribution.

—*Carex testacea*; mingled with *Carex virgata* in south corner.

—*Scirpus nodosus*.

A turf, consisting of mosses, grasses and herbs as listed in the text, increases in amount from south to north, becoming practically continuous over the north-east portion.

Fig. 23.

PLAN DIAGRAM OF QUADRAT III, 26th April to 14th May, 1946. Except for areas indicated, the quadrat is uniformly covered by sward composed of lichens, mosses, grasses and herbs listed in the text.

LE —Patches of *Leptospermum ericoides*, low and wind-swept.

—*Scirpus nodosus*.

See also text for list of species growing beneath patches of *Leptospermum ericoides*.

Arrows G-N indicate approximate position and angle of photographs (Figs. 9 to 14, and 18).

PLATE 52.